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ENERGY EFFICIENCY IMPROVEMENT IN AIR CONDITIONERS AFTER REPAIR AND MAINTENANCE PROCESS

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Abstract

This study aims to analyze the improvement in energy efficiency of air conditioning (AC) systems after repairs and routine maintenance. The use of unmaintained AC units leads to an increase in energy consumption, which results in higher operational costs. This research measures the changes in electrical power consumption and cooling capacity at two locations: the village office and a residential house. The results show a 25% reduction in power consumption at both locations after the repairs were made, as well as an 8.6% improvement in cooling capacity at the village office and a 13.6% improvement at the residential house. The study also identifies factors that affect energy efficiency, such as refrigerant leaks and component cleanliness. The findings of this study are expected to provide insights into the importance of maintenance and repairs for AC systems to enhance energy efficiency

Keywords: ***Energy Efficiency, Air Conditioner, Repair, Refrigerant, Maintenance***

INTRODUCTION

Air conditioning (AC) systems have become an indispensable component of modern daily life, particularly in tropical regions such as Indonesia, where elevated ambient temperatures substantially influence thermal comfort within enclosed environments.(Issue et al., 2023) However, over time, the energy efficiency of air conditioning systems may decrease due to various factors, such as dust accumulation on filters, refrigerant leakage, or damage to other components.(Rozaq et al., 2019) This deterioration in efficiency not only leads to increased energy consumption, but also contributes to higher operational expenditures and exacerbates environmental impacts.(Zeng et al., 2025)The operation of air conditioning systems is governed by the fundamental principle of the vapor-compression refrigeration cycle, which entails the thermodynamic phase transitions of the working refrigerant between gaseous and liquid states.(Nasution et al., 2020) This process occurs through four main stages: compression, condensation, expansion, and evaporation.(Kevin et al., 2022)(Issue et al., 2023) In the compression stage, the gaseous refrigerant is compressed by the compressor and pumped to the condenser, where it releases heat and turns into a liquid.(Soewono et al., 2023) In the expansion stage, the refrigerant that has turned into a liquid experiences a decrease in pressure, which then enters the evaporator, where it absorbs heat from the indoor air and returns to a gas. This process continues to repeat itself, keeping the room temperature low.(Handbook, 2019)(Ra, 2025)

The thermodynamic principles underlying the operation of air conditioners are essential to understanding energy efficiency in these systems.(Poernomo et al., 2015) The first law of thermodynamics (conservation of energy) states that energy cannot be created or destroyed, but it can change form.(Tharo et al., 2025a) In the context of air conditioning, heat energy from indoor air is transferred to the outdoors using electrical energy to drive a compressor.(*Dasar – Dasar Air Conditioner (AC) Split*, n.d.) The second law of thermodynamics states that heat will always flow from a hotter place to a cooler place.(*Dasar – Dasar Air Conditioner (AC) Split*, n.d.) AC systems utilize this principle to transfer heat from indoor air to outdoor air. Regular AC maintenance is essential to ensure the system is working efficiently.(Nasution et al., 2020)(Issue et al., 2023)(Tharo et al., 2025b) Preventive maintenance, such as filter cleaning, checking refrigerant pressure, and repairing refrigerant leaks, can prevent a decrease in efficiency and extend the life of the system.(Anis et al., 2024) Previous studies have shown that repairing air duct leaks and proper refrigerant charging can significantly improve the energy efficiency of an AC system.(Issue et al., 2023)(Zeng et al., 2025)

Decreased energy efficiency in AC can cause increased power consumption which leads to high operational costs.(Tharo et al., 2025b)(Anisah et al., 2021) Therefore, this study aims to analyze the energy efficiency improvements of air conditioners after periodic repairs and maintenance. This research is expected to provide insight into how improvements to AC systems can reduce energy consumption and improve system performance, as well as provide practical recommendations for AC users to optimize energy use and reduce operational costs.

Some factors that affect energy efficiency in AC include:

1. Refrigerant Leak:
   Refrigerant leaks in the AC system can cause reduced cooling capacity and increased power consumption.(Nasution et al., 2020) The compressor has to work harder to reach the desired temperature, thus increasing energy consumption.
2. Filter and Coil Condition**:**
   Dirty filters and dusty condenser coils can restrict airflow, reduce heat transfer efficiency, and force the system to work harder.(Poernomo et al., 2015) Regular cleaning of filters and coils can improve airflow and energy efficiency.
3. Temperature Settings:
   Setting the temperature too low causes the AC to work harder to reach the desired temperature, which leads to wasted energy.(Kevin et al., 2022)(Soewono et al., 2023) Keeping the temperature at an efficient level can reduce the system workload and save energy.
4. Age and Condition of Components**:**
   Over time, components such as the compressor, condenser, and evaporator can experience a decline in performance.(*Dasar – Dasar Air Conditioner (AC) Split*, n.d.) Regular maintenance and replacement of damaged or worn components is essential to maintain system efficiency.

LITERATURE REVIEW

1. Energy Efficiency in AC Systems

The energy efficiency of an air conditioning (AC) system is determined by the system's ability to transfer heat with minimal electricity consumption. When heat transfer is optimal, electrical energy consumption can be minimized. However, in poorly maintained ACs, heat transfer resistance increases, forcing the compressor to work harder and extending the unit's operating time. This results in high electricity consumption. This decrease in efficiency is common in ACs used in tropical regions like Indonesia, where the cooling load is relatively high year-round.

2. Refrigeration Cycle and System Performance

An air conditioning system operates through a refrigeration cycle consisting of compression, condensation, expansion, and evaporation. System efficiency depends heavily on the condition of components such as the compressor, condenser, and evaporator, as well as the amount of refrigerant within the closed system. If any of these components malfunctions, the thermodynamic balance is disrupted, resulting in reduced cooling capacity and increased power consumption.

3. Factors Causing Decrease in Energy Efficiency

Based on previous studies, there are several main factors that cause a decrease in energy efficiency in AC:

Table 1. Factors Causing Decreased Efficiency in AC

Factor	Impact on The System
Refrigerant leak	Reduces heat absorption capacity → compressor works longer
Dirty air filter	Reduce air flow → condenser cannot release heat optimally
Condition of condenser/evaporator coil is dusty	Heat transfer resistance increases → energy is wasted
Temperature setting too low	The system operates at maximum load continuously.

Poor maintenance will accelerate the decline in system performance. The study in this journal also showed that this condition occurred in AC units before repairs were performed.

4. The Role of Maintenance and Repair in Energy Efficiency

Regular maintenance, such as filter cleaning, refrigerant pressure checks, and replacement of worn components, is a proven technical strategy for improving energy efficiency. Preventive maintenance can reduce compressor workload, thereby reducing energy consumption and extending system life.

The research results in this study show:

- 25% reduction in power consumption after repair
- Increased cooling capacity by 8.6% and 13.6%
- Refrigerant leaks and filter condition are the dominant factors in reducing energy efficiency.
  These findings support the literature that repairs and maintenance have a direct impact on energy savings

5. Research Gap

Based on previous research, many studies have focused solely on:
• AC efficiency in large-scale industries
• HVAC systems in commercial buildings
• Use of environmentally friendly refrigerants
However, studies on AC energy efficiency in households and village offices using a direct approach before and after repairs are still limited.
This study fills this gap with field measurements based on power consumption and cooling capacity data.

Conceptual Framework

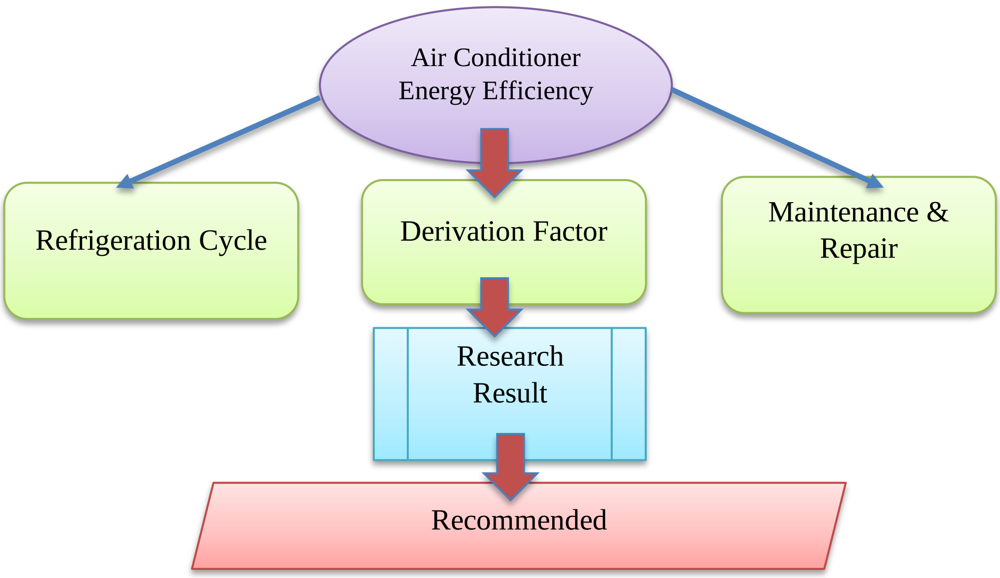

Figure 1. Conceptual Framework

Explanation of Mind Map Structure

Conceptual Center: Air Conditioning Energy Efficiency
Main branches radiating outward:
1. Refrigeration Cycle
2. Efficiency Deterioration Factors
   o Refrigerant Leaks
   o Dirty Filters/Coils
   o Ineffective Temperature Control
3. Maintenance & Repair
4. Research Results
   o 25% Power Reduction
   o Increased Cooling Capacity
5. Recommended Use

Research Hypothesis

A. Main hypothesis (paired t-test)

1. $H0_1$: The average AC power consumption before and after repair/maintenance is not different. (μ_power, difference = 0).

$H1_1$ (arah): Average power consumption decreases after repair/maintenance (μ_power, difference < 0).

2. $H0_2$: The average cooling capacity of the AC before and after repair/maintenance is not different. (μ_capasity, difference = 0).
   $H1_2$ (direction): Average cooling capacity increases after repair/maintenance (μ_capasity, difference > 0).

B. Hypothesis of efficiency determinants (linear regression)
Use power consumption (kWh/hour) as the dependent variable (smaller = more efficient). Independent variables according to the repair/maintenance protocol:

3. $H0_3$: Refrigerant leaks do not affect power consumption ($\beta_1 = 0$).
   $H1_3$ (direction): Refrigerant leaks increase power consumption ($\beta_1 > 0$).
4. $H0_4$: The condition of the filter/coil does not affect power consumption. ($\beta_2 = 0$).
   $H1_4$ (direction): Filter/coil gets dirtier → power consumption increase ($\beta_2 > 0$).
   (If encoded "1 = dirty, 0 = clean", expektation $\beta_2 > 0$. If you use a cleanliness index, the bigger the = the cleaner, the expectation is $\beta_2 < 0$.)
3. $H0_5$: Temperature set-point has no effect on power consumption ($\beta_3 = 0$).
   $H1_5$ (direction): Lower set-point (colder) → higher power consumption ($\beta_3 < 0$ if the variable = "degrees °C", because lower means a smaller number).

C. (Optional) Cross-site hypothesis

6. $H0_6$: The reduction in power consumption after the repair was the same between the village office and residents' homes.
   $H1_6$:. Power consumption reduction differs between locations (e.g. greater at locations with worse initial conditions)

RESEARCH METHODS

Types of Research

This research uses a quantitative approach with an experimental design, this research is more systematic in conducting research to analyze the increase in energy efficiency in the AC system after repairs and maintenance.(*Buku Ini Di Tulis Oleh Dosen Universitas Medan Area Hak Cipta Di Lindungi Oleh Undang-Undang Telah Di Deposit Ke Repository UMA Pada Tanggal 27 Januari 2022*, 2022)

Location and Research Sample

This research was conducted in two different locations, namely the Village Office and Residents' Homes in Petumbukan Village, Galang District, Deli Serdang Regency, North Sumatra. These two locations were chosen because they have representative conditions for AC which is often used in household and office environments in tropical areas. In each location, the AC system used is a Split AC with a capacity of 1 PK. The research sample consisted of two AC units in each location that had previously experienced a decrease in energy efficiency.

Air Conditioner Repair and Maintenance

Air Conditioner repairs include the following steps:

- Filter Cleaning: A dirty air filter can restrict air flow, increase power consumption, and reduce cooling capacity. Therefore, the filter is cleaned using water and a cleaning agent safe for AC components.
- Refrigerant Check and Recharge: The refrigerant pressure is measured to ensure the refrigerant level in the system is at an optimal level. If a leak or low refrigerant level is found, the refrigerant is recharged to the required capacity.
- Component Check: The compressor, condenser, and evaporator are inspected for damage or worn components. If damage is found, the necessary components are repaired or replaced.

Data Collection

Data collection was conducted through direct measurements of the electrical power consumption and cooling capacity of the air conditioning system before and after repairs. The data collection method was as follows:

- Electrical Power Consumption:

Power consumption was measured using a wattmeter installed on the AC system. Measurements were taken under two conditions: (1) before the repairs were made and (2) after the repairs were made. Each measurement was taken over a 1-hour period to obtain consistent results.

- Cooling Capacity:
  Cooling capacity was measured using a digital thermometer installed in the room cooled by the AC system. The room temperature was measured every 15 minutes to determine temperature fluctuations before and after the repairs. Additionally, measurements were taken to determine how quickly the temperature reached the desired value (24°C) after the system was turned on.

Data Analysis Techniques

To analyze the data obtained, several statistical techniques were used as follows:

- Descriptive Analysis: The data obtained will be analyzed descriptively to describe the average power consumption and cooling capacity values under both conditions (before and after repair). The average, standard deviation, and percent change will be calculated to provide an overview of the efficiency of the AC system.(*Buku Ini Di Tulis Oleh Dosen Universitas Medan Area Hak Cipta Di Lindungi Oleh Undang-Undang Telah Di Deposit Ke Repository UMA Pada Tanggal 27 Januari 2022*, 2022)
- Paired Sample T-test: To test whether improvements to the AC system significantly impact power consumption and cooling capacity, a paired-samples t-test was used. This test compares the average values between two conditions (before and after improvements) within the same group (i.e., the same AC system before and after improvements). The results of the t-test will provide information on whether the improvements have a significant impact.(*Buku Ini Di Tulis Oleh Dosen Universitas Medan Area Hak Cipta Di Lindungi Oleh Undang-Undang Telah Di Deposit Ke Repository UMA Pada Tanggal 27 Januari 2022*, 2022)
- Linear Regression Analysis: Regression analysis is used to determine the factors that influence energy efficiency in AC systems. (*Buku Ini Di Tulis Oleh Dosen Universitas Medan Area Hak Cipta Di Lindungi Oleh Undang-Undang Telah Di Deposit Ke Repository UMA Pada Tanggal 27 Januari 2022*, 2022) Factors such as refrigerant leaks, filter condition, and temperature settings will be analyzed to determine their impact on reducing power consumption. A simple linear regression model will be used to examine the relationship between these factors and power consumption.

Validity and Reliability

To ensure the accuracy and consistency of the results, this study used calibrated measuring instruments (Anisah et al., 2021) and repeated measurements are performed to reduce the potential for measurement errors. Furthermore, AC maintenance is performed by experienced technicians to ensure that all repair and maintenance steps are carried out according to standard procedures. This study adopts an experimental approach to obtain valid and objective data.(*Buku Ini Di Tulis Oleh Dosen Universitas Medan Area Hak Cipta Di Lindungi Oleh Undang-Undang Telah Di Deposit Ke Repository UMA Pada Tanggal 27 Januari 2022*, 2022) regarding changes in power consumption and cooling capacity of the AC system. By using appropriate measurement tools and relevant statistical analysis, the results of this study are expected to provide insight into the importance of AC maintenance to improve energy efficiency and reduce operational costs.

For more details on the research stages, please see the following flowchart:

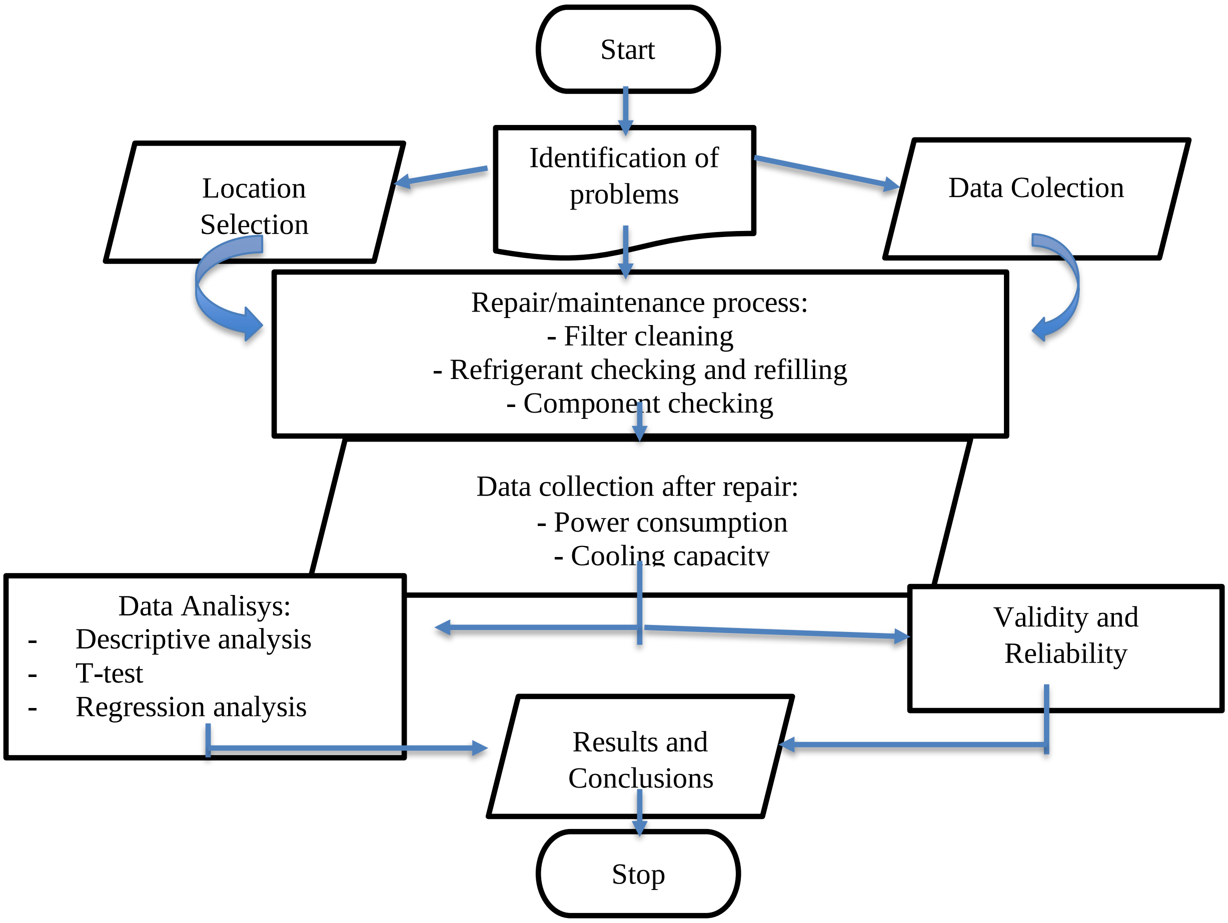

Figure 2. Flowchart

RESULTS AND DISCUSSION

Results

The research was conducted at two different locations: a village office and a resident's home, both of which used a 1-HP split AC unit. The AC units had been in use for over two years, had never been repaired, and had not had any maintenance for over three months.

From the research conducted, the results obtained are as in the table below:

Table 2. Power Consumption Measurement Before and After Repairs to the AC System

Location	Before Repair		After Repair		Decline (%)
	Power consumption (kWh/ Hour)	Room Temperature (°C)	Power consumption (kWh/Hour)	Room Temperature (°C)	
Village Office	1.2	27 – 29	0.9	24 – 25	25%
Resident's House	0.8	28 – 30	0.6	25 – 26	25%

The reduction in power consumption at both locations demonstrated significant energy savings following the AC repairs, with a 25% reduction in power consumption. In the village office, the room temperature stabilized at 24°C to 25°C after the repairs, while in residents' homes, the temperature became more comfortable at 25°C to 26°C.

Figure 3. Comparison Chart of Power Consumption Before and After Repair

This graph shows a significant reduction in power consumption after the improvements, by 25% each at both locations.

Table 3. Increased Cooling Capacity After Repair

Location	Cooling Capacity Before Repair (kW)	Cooling Capacity After Repair (kW)	Improvement (%)
Village Office	3.5	3.8	8.6%
Resident's House	2.2	2.5	13.6%

The analysis showed a more significant increase in cooling capacity in the residential home, likely due to the system's poorer condition prior to the repairs. At both locations, the repairs increased cooling efficiency and reduced temperature fluctuations.

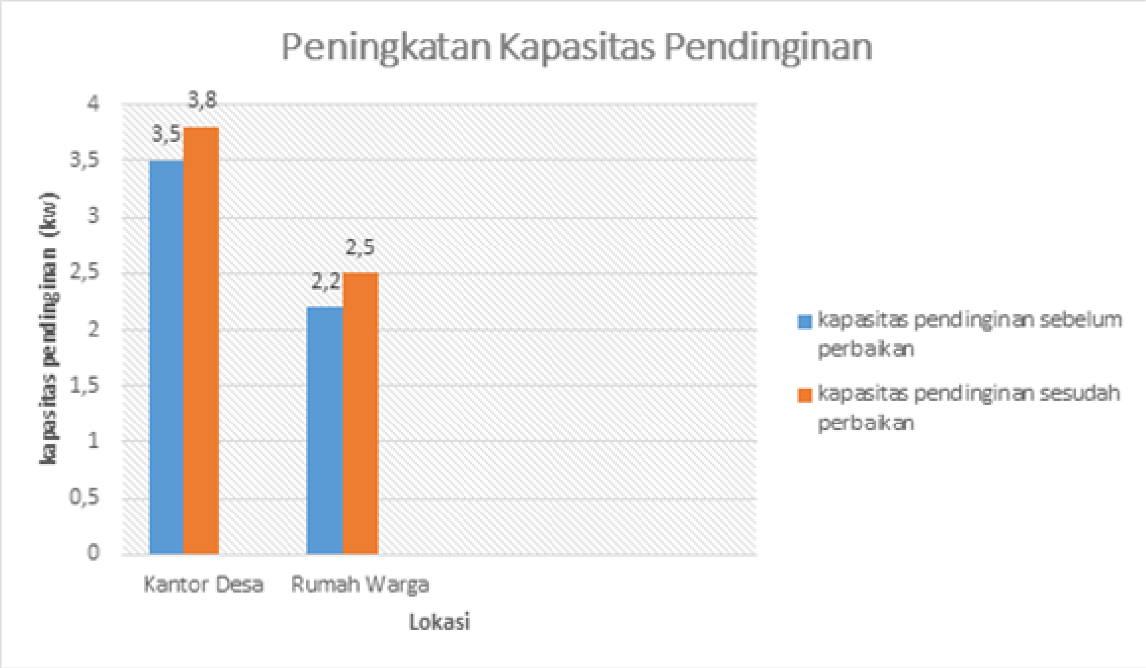

Figure 4. Comparison Chart of Cooling Capacity Increase Before and After Repair

This graph shows the increase in cooling capacity after the repairs, with an increase of 8.6% at the Village Office and 13.6% at the Residents' Houses, respectively.

Statistical Analysis

To measure whether AC system improvements significantly impact power consumption and cooling capacity, a Paired Samples T-Test is used. This test compares the average power consumption before and after improvements to the same AC system.

Table 4. T-Test Results for Power Consumption

Location	Average Value Before Repair (kWh/Hour)	Average Value After Repair (kWh/Hour)	Difference (kWh/Hour)	T-Test	P value
Village Office	1.2	0.9	-0.3	3.41	0.005
Resident's House	0.8	0.6	-0.2	2.89	0.010

Information:

A t-test was used to examine the difference in average power consumption before and after the improvements.

The p-value indicates the significance of the test results, with a p-value <0.05 indicating a significant change.

The T-test results showed a p-value <0.05 for both locations, indicating that AC system improvements significantly reduced power consumption. At the village office, power consumption decreased by 25%, while the same decrease occurred in residents' homes.

Figure 5. Refrigerant Checking and Filling

Regression Analysis

In addition to the T-test, a simple linear regression analysis was also carried out to analyze the relationship between factors that influence energy efficiency, such as refrigerant leaks, filter conditions, and temperature settings, towards reducing power consumption.

Table 5. Simple Linear Regression Model

Independent Factors	Regression Coefficient	Standard Error	P Value
Refrigerant Leak	-0.15	0.05	0.02
Filter Condition	-0.10	0.04	0.04
Temperature Settings	-0.05	0.02	0.09

Information:

The regression model showed that refrigerant leaks and filter condition significantly reduced power consumption (p-value < 0.05).

Temperature control, while influential, did not show a significant effect (p-value > 0.05).

The regression analysis revealed that refrigerant leaks and filter condition were the primary factors affecting energy efficiency in AC systems. Repairing refrigerant leaks and cleaning filters significantly reduced power consumption.

Discussion

Based on previous research, several important findings have been identified that relate to the energy efficiency of air conditioning (AC) systems after repairs and maintenance. This research shows that repairs to poorly maintained AC systems can significantly improve energy efficiency.(Zeng et al., 2025) The research results showed a 25% reduction in power consumption at two different locations, namely the village office and residents' homes, after periodic repairs and maintenance were carried out on the AC system. The reduction in power consumption and increase in cooling capacity recorded after the improvements were made indicate significant energy savings.(Anis et al., 2024)(Pujiastuti & Leo, 2025) This is in line with previous findings which stated that refrigerant leaks and dirty filters are the main factors that can reduce energy efficiency in Air Conditioner systems.(Poernomo et al., 2015) In the study, cleaning the filter and checking and refilling the refrigerant were shown to reduce power consumption, which is also supported by previous studies that highlight the importance of regular Air Conditioner maintenance.(Issue et al., 2023)

In addition, the linear regression analysis in this study also identified that factors such as refrigerant leakage and filter condition play an important role in reducing power consumption.(Ra, 2025) This research underscores the importance of focused improvements in both areas, which have been shown to significantly reduce energy use. This is also supported by previous research showing that unrepaired refrigerant leaks can force the compressor to work harder, increasing power consumption and reducing cooling capacity.(Rozaq et al., 2019) Overall, the results of this study are consistent with existing literature findings regarding the importance of AC system maintenance to improve energy efficiency. With proper maintenance, AC systems can not only save energy and operating costs but also extend their lifespan.(Soewono et al., 2023) Therefore, this study provides deeper insights into how regular air conditioning maintenance can contribute to reducing energy consumption and improving thermal comfort in various environments.

CONCLUSION

The conclusion of this study confirms that regular repair and maintenance of air conditioning (AC) systems have a significant impact on energy efficiency and system performance. This study successfully demonstrated that AC maintenance, which includes filter cleaning, refrigerant checking and refilling, and repairing refrigerant leaks, substantially reduces power consumption and increases cooling capacity. These findings align with the study's objective of analyzing the effect of maintenance on energy efficiency, which directly contributes to operational cost savings and improved thermal comfort. The primary contribution of this research is to emphasize the importance of AC system maintenance as a practical solution to reduce energy consumption and operational costs. Furthermore, it provides insight into factors affecting energy efficiency, such as refrigerant leaks and filter condition, which are crucial for maintaining the sustainable performance of AC systems. Through statistical and regression analysis, this study successfully identified that improvements in these factors had a significant impact on reducing power consumption.(Anis et al., 2024)[13] Overall, this study not only answers the question of how improvements can improve energy efficiency in air conditioners, but also provides practical recommendations for air conditioner users to perform routine maintenance to optimize energy use and reduce environmental impact. Therefore, the findings of this study can serve as a basis for energy efficiency policies in the residential and office sectors, and can be adopted in more sustainable energy management practices.

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